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EFFLUENT VARIABILITY IN THE MEAT-PACKING AND POULTRY PROCESSING INDUSTRIES

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Corvallis, Oregon

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16. ABSTRACT Long-term BOD_5 and suspended solids (SS) wastewater quality data on six meat-packing and four poultry processing plants was analyzed with respect to its variability. Results were compared to the discharge limitations for the respective industry categories and parameters. Summary and conclusions are:

1. For a treatment system to produce an effluent capable of meeting the maximum daily limitation, an average less than the 30-day average limitation must be achieved.
2. Per capability of meeting the 1977 discharge limitations, meat-packing plants appear to meet BOD_5 limitations but for SS the maximum daily value is critical. Poultry processing plants are in existence that meet 1977 BOD_5 and SS limitations. In addition, one plant is meeting the 1983 BOD_5 average and maximum limitations, and average limitations for SS.
3. Plants that had a lower water use tended to correspondingly have a lower waste load.
4. Periods of high effluent load corresponded with periods of abnormal weather conditions.
5. There is no conclusive evidence as to the variability of the effluent with respect to winter-summer. Overall performance of a treatment plant appeared to have no effect on the variability with respect to the seasons.
6. There is some question as to the enforceability of the maximum limitation.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Food Processing, *Industrial Wastes, Industrial Water, Effluents, Variability, Statistical Analysis, Biochemical Oxygen Demand, Industrial Wastewater Treatment	*Meat-Packing Industry, *Poultry Processing Industry, Effluent Variability, Discharge Limitations, Waste Load, Weather Effects, Seasonal Effects, Waste Water Volume	1302

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INDUSTRIAL WASTES BRANCH

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June 1975

EFFLUENT VARIABILITY IN THE MEAT-PACKING AND POULTRY PROCESSING INDUSTRIES

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James F. Scaief*

INTRODUCTION

Increased industrialization has resulted in higher waste loadings on receiving bodies of water and has caused regulatory agencies to require increasingly more stringent effluent standards. These standards, in addition to five-day biochemical oxygen demand (BOD_5) and total suspended solids (TSS), include parameters such as ammonia-nitrogen (NH_3-N), oil and grease (O&G), fecal coliform, and pH.

Tables 1 and 2 summarize the guidelines established for the red meat industry and recommended for the poultry processing industry.

For many meat-packing and poultry processing plants to meet these new guidelines, much needs to be accomplished in controlling their effluent variability. As stated by Ford (1), an inherent variability is attributed to the treatment system, the characteristics of the raw waste load, and geographical and climatological conditions. Therefore, to minimize the variability one needs to take a look at each factor contributing to this variability and determine what control measures are possible. Analyses of in-plant processes will be necessary and in some cases newer processes may have to be introduced. Provisions might be made to minimize storm water runoff entering the system. The existing

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Table I. RED MEAT EFFLUENT STANDARDS

Federal Register, Vol. 39, No. 41, 2/28/74

Maximum average of daily values for a 30 consecutive day period

(kg/kkg LWK)

Plant Subcategory	7/1/77 Best Practical Treatment BOD_5	TSS	O&G	New Sources NH_3-N	7/1/83 Best Available Treatment BOD_5	TSS
Slaughterhouse:						
I. Simple	.12	.20	.06	.17	.03	.05
II. Complex	.21	.25	.08	.24	.04	.07
Packinghouse:						
III. Low-Processing	.17	.24	.06	.24	.04	.06
IV. High-Processing	.24	.31	.13	.40	.08	.10

pH limit is 6.0-9.0

Fecal coliform maximum limit is 400 mpn/100 ml.

Maximum for any 1 day is 2X the average.

1983: O&G, Maximum = 10 mg/l

NH_3-N, Maximum = 8 mg/l

guidelines and the probable inclusion of nutrients in effluent standards will, in many cases, require the industries to install further treatment beyond existing secondary treatment. If an industry elects to discharge to a municipal system, pretreatment might be required.

Table 2. POULTRY PROCESSING: RECOMMENDED EFFLUENT LIMITATIONS

EPA Contract No. 68-01-0593

Average Limitation

(kg/kkg LWK)

Plant Subcategory	7/1/77 Best Practical Treatment			7/1/83 Best Available Treatment		
	BOD_5	TSS	O&G	BOD_5	TSS	O&G
Chickens	.46	.62	.20	.30	.34	.20
Turkey	.36	.57	.14	.21	.24	.14
Fowl	.61	.72	.15	.23	.27	.15
Ducks	.77	.90	.26	.39	.46	.26

Fecal coliform maximum limit is 400 mpn/100 ml.

NH_3-N: New Source and 1983 limit is 4 mg/l.

1983: TKN = 4 mg/l, TP = 2 mg/l, NO_3/NO_2-N = 5 mg/l.

Through analysis of data from existing outstanding meat packing, slaughtering and poultry processing plants, it is hoped to identify those combinations of in-plant controls and subsequent wastewater treatment processes which are most efficient in meeting discharge regulations.

Primary ob,ectives:

1. Determine in-plant controls which produce least magnitude and variability in treated effluent loads.

2. Determine treatment system or systems used to produce least magnitude and variability in effluent loads.

3. Determine what percentage of time plant discharge meets established effluent limits.

4. Determine causes when limits are exceeded.

5. Determine the level beyond which a treatment plant ceases to provide effective treatment.

Information needed:

Records on:

1. Production

2. Effluent flow

3. Effluent compositions
   a. Untreated
   b. Treated

4. In-plant process description

5. Treatment plant design

RESULTS

Data Search

Data was obtained for this project from individual state pollution control agencies, the U.S. Department of Agriculture, North Star Research Institute, and private industry in addition to EPA.

Initially it was decided that in order to have a meaningful statistical analysis, at least 40 data points for the various wastewater quality parameters would be needed. This alone limited the number of plants for which data would be available.

Due to the lack of a regular reporting system in many states, only those plants that were believed to be producing a poor quality effluent were monitored regularly. This study is concerned with the more exemplary plants, and consequently there is little information available. Originally it was intended to evaluate the treatment systems with respect to biochemical oxygen demand, chemical oxygen demand, suspended solids, oil and grease, ammonia nitrogen, and phosphorus. It was found that data on parameters other than BOD_5 and SS was very limited, and as a result, comparison of the different types of treatment systems with respect to the other parameters was not possible.

Meat: Raw Wastewater

Table 3 shows the mean water use as well as raw BOD_5 and SS wastewater loads from meat-packing plants. The two plants showing the lowest mean values for BOD_5 and SS are 8A and 9A with values of 10.2 and 8.1 kg BOD_5/kkg LWK and 10.0 and 8.4 kg SS/kkg LWK, respectively. Another plant, 1A, even though the mean BOD_5 and SS loads are not quite as low, does exhibit a variability that is minimal as can be seen by the

Table 3. RAW WASTEWATER CHARACTERISTICS

Plant	Effluent Guidelines Category	BOD_5[a] Mean	Max	Std. Dev.	N[b]	SS[a] Mean	Max	Std. Dev.	N	Water Use[c]
1A	II	10.7	18	3.8	45/26	12.8	24	4.5	46/26	4.38 (525)
3A	II	23.7	33	4.9	34/12	17.7	27	3.1	35/12	15.60 (1870)
4A	III	12.0	23	7.8	49/37	13.0	27	13	48/37	8.29 (993)
7A	II	18.0	45	10.6	33/17	14.4	36	10	30/17	9.27 (1111)
8A	II	10.2	21	5.3	91/24	10.0	21	6.4	91/24	7.89 (946)
9A	II	8.1	15	3.1	42/11	8.4	16	7.5	53/11	8.44 (1012)

[a]Values in kg/kkg LWK

[b]N = number of observations/number of months in observation period

[c]Water use in m^3/kkg (gal/1000 lb)

standard deviations. At the other end of the scale are plants 3A and 7A with raw wastewater loads of 23.7 and 18.0 kg BOD_5/kkg LWK and 17.7 and 14.4 kg SS/kkg LWK, respectively. Figures 1 and 2 show probability curves developed to graphically show the variability of the effluent.

It is difficult to pinpoint the reasons for the lower wasteloads without conducting an in-plant survey; therefore, conclusions have to be drawn based on the processing plant raw wasteload. For the above plants, one feature that might explain the differences is water use. In Table 3, plants 1A, 8A, and 9A, the three plants with the lowest water use for category II, are also the ones mentioned above exhibiting the least raw wastewater load. Plant operations that could contribute toward this lower water use are better housekeeping practices and making use of dry cleanup prior to washdown. Another significant factor in water use reduction is the installation of high pressure nozzles on water outlets.

Meat: Final Effluent

Results of different treatment systems employed in the meat-packing industry are presented in Table 4. All make use of a biological secondary system, either an anaerobic-aerobic lagoon system or an anaerobic contact process followed by aerobic lagoons.

As can be seen from the aforementioned table and Figure 3, comparing the results with the effluent limitations presented previously shows that only one of the plants could not meet the 1977 mean BOD_5 limits for its respective category and that the maximum value was exceeded by five of the six. Figures 4 and 5 show probability curves developed to graphically show the BOD_5 variability of the effluent.

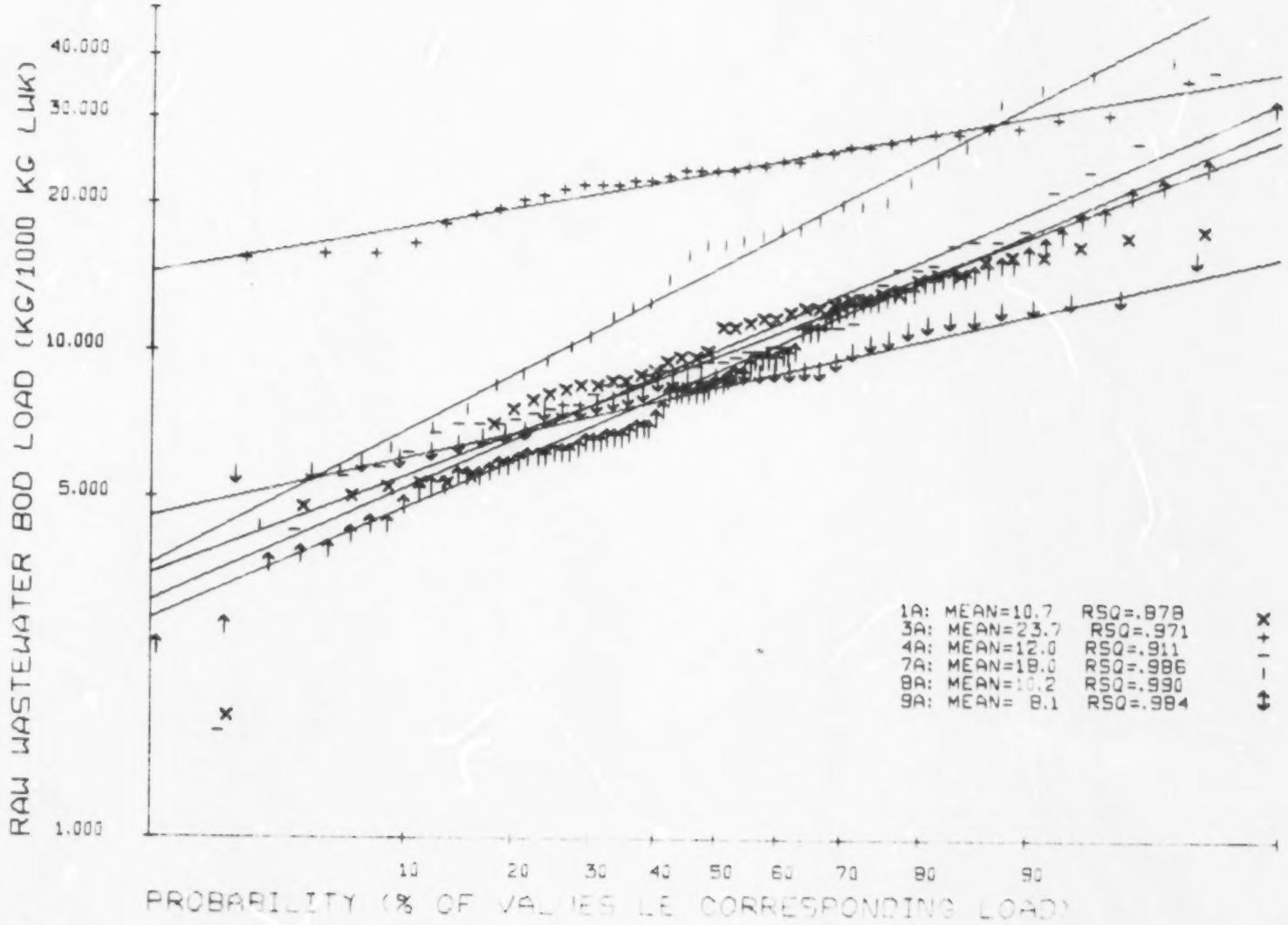

Figure 1. Log-Probability representation of [illegible] BOD_5 waste load.

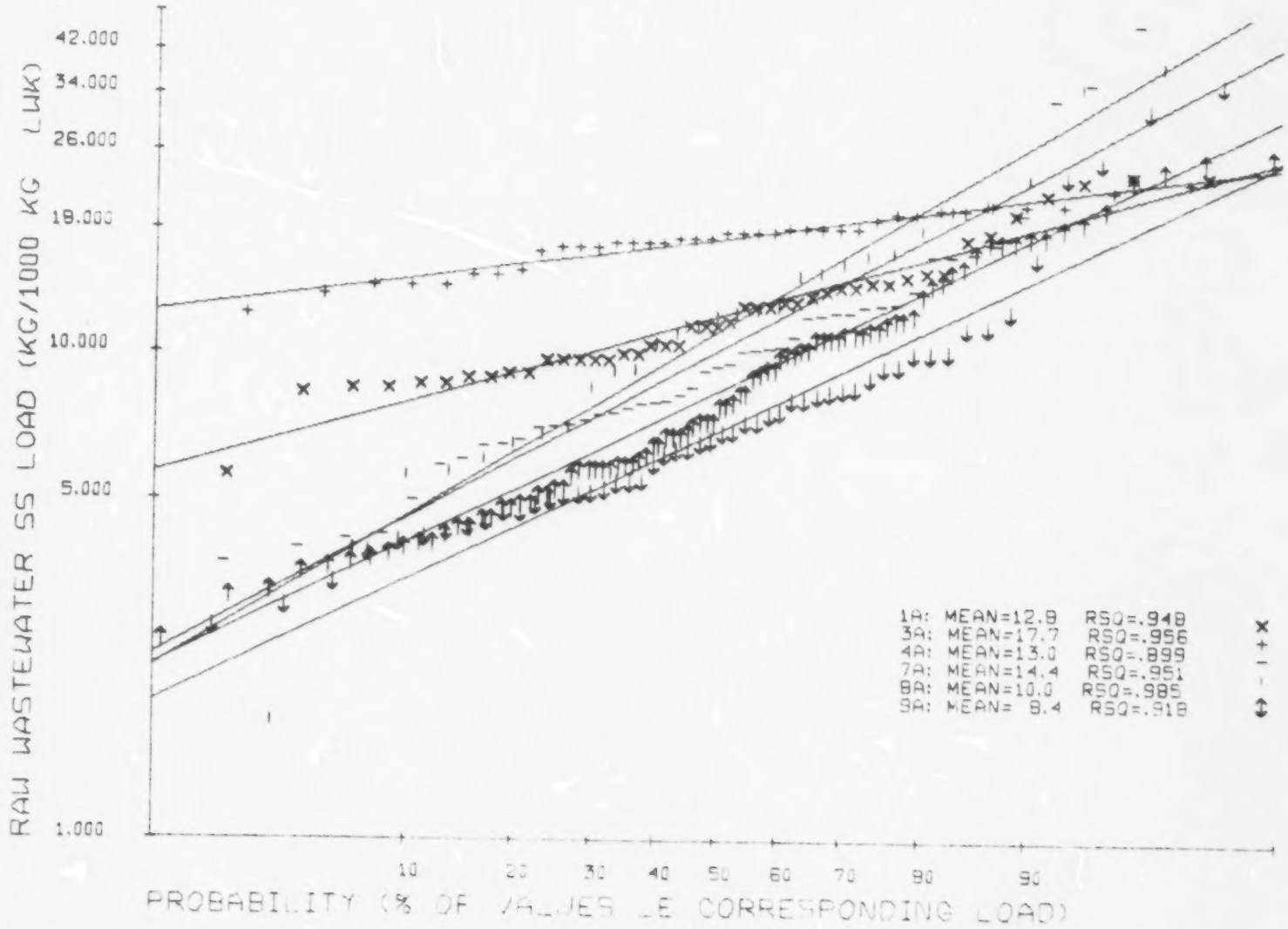

Figure 2. Log-Probability regression of west-wacking plant raw SS waste load.

Table 4. FINAL EFFLUENT CHARACTERISTICS

Plant	Effluent Guidelines Category	BOD_5[a] Mean	Max	Std. Dev.	N[b]	SS[a] Mean	Max	Std. Dev.	N
1A	II	.13	.58	.13	43/27	.33	2.31	.37	46/27
3A	II	.11	.23	.06	29/14	.30	1.15	.22	29/14
4A	III	.16	.55	.10	32/36	.67	1.95	.47	28/36
7A	II	.33	1.45	.26	49/29	.34	1.52	.34	46/29
8A	II	.14	.46	.10	92/24	.43	1.55	.32	32/24
9A	II	.21	.62	.15	42/11	.44	1.56	.31	53/11

[a]Values in kg/kkg LWK

[b]N = number of observations/number of months in observation period

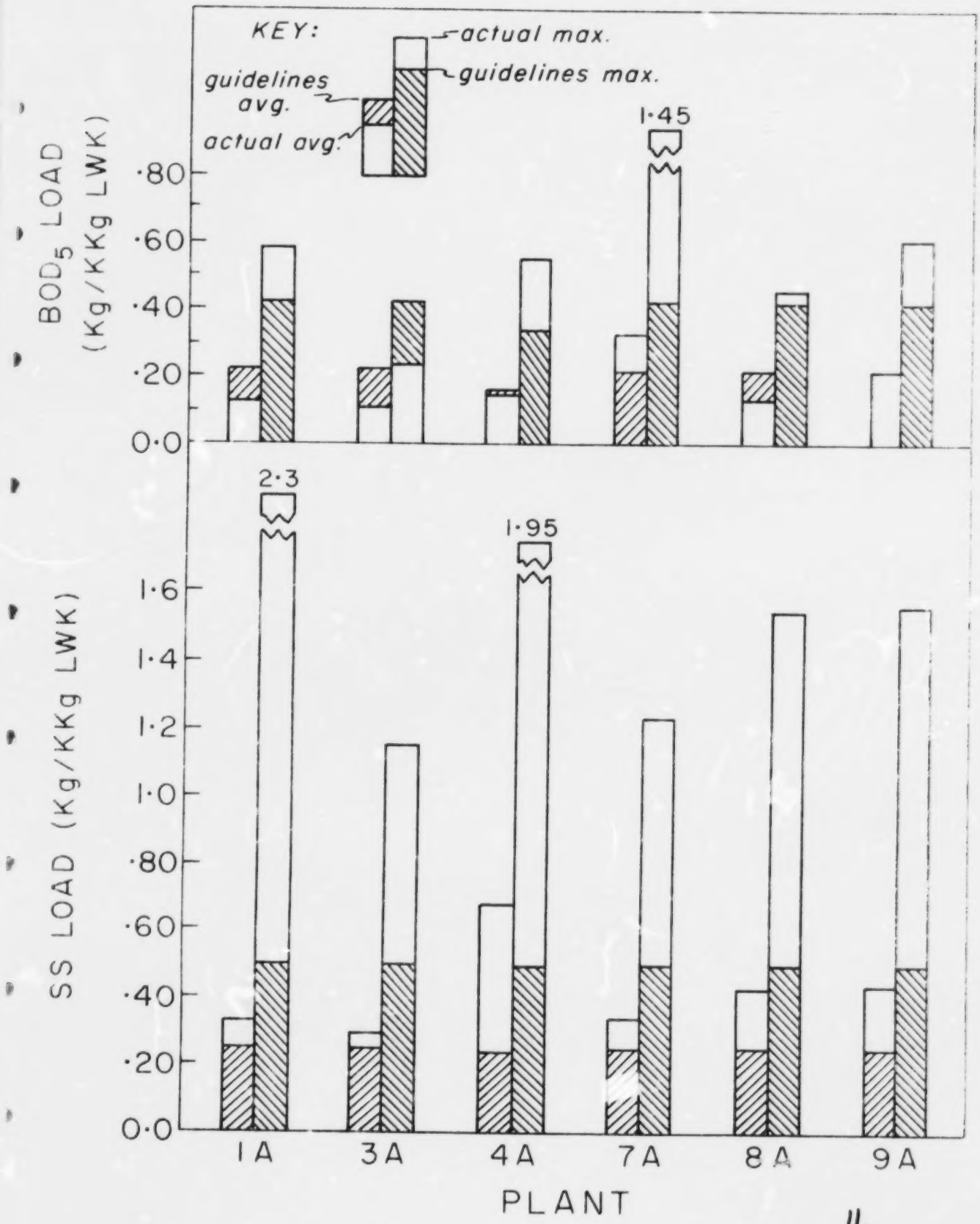

Figure 3. BOD_5 and SS actual vs. 1977 guidelines 30-day average and daily maximum.

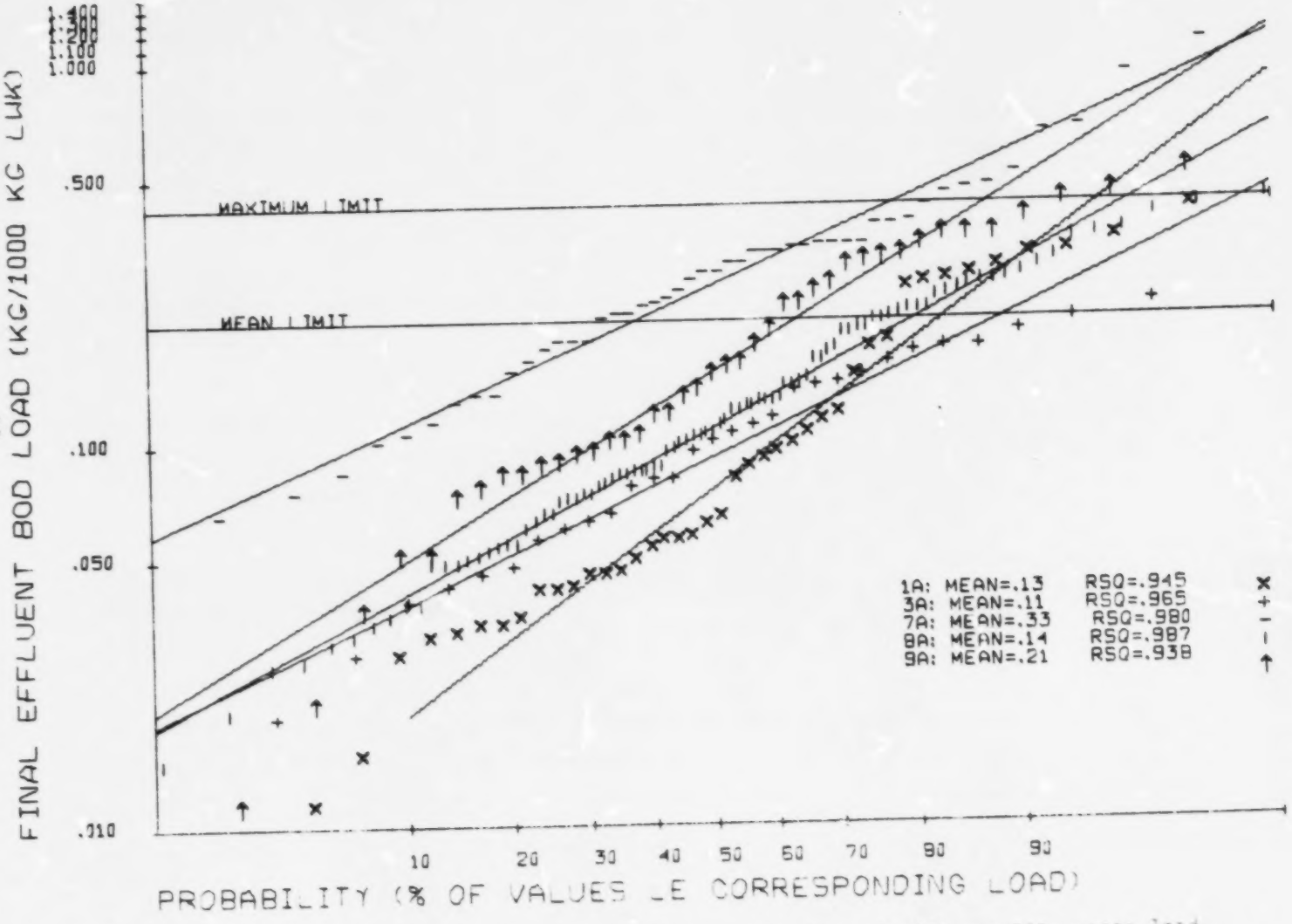

Figure 4. Log-Probability representation of meat-packing plant final effluent BOD_5 waste load, category II plants.

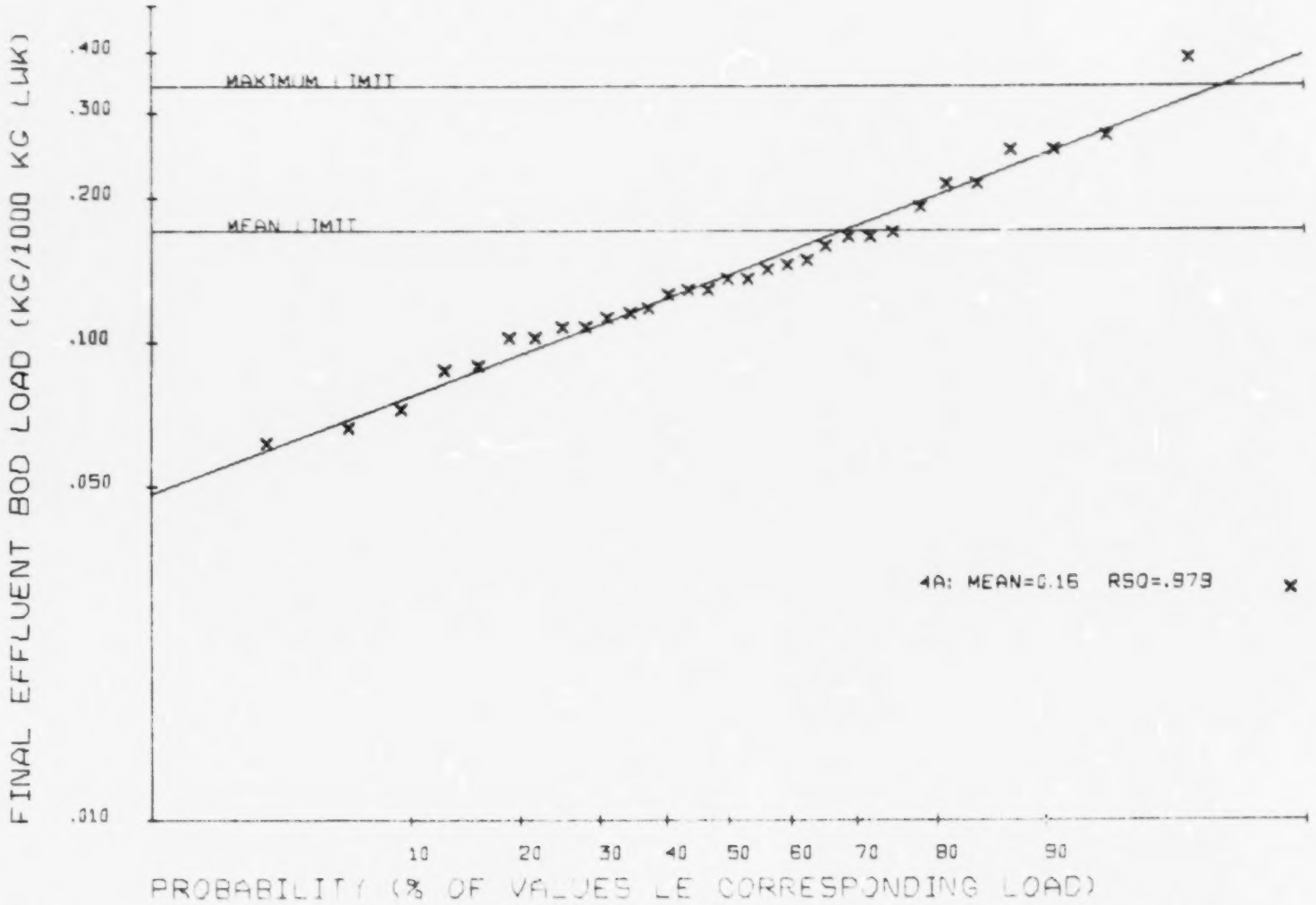

Figure 5. Log-Probability representation of meat-packing plant final effluent BOD_5 waste load, Category III plant.

From Figures 3, 6 and 7 it can be seen that of the plants under consideration in this evaluation, none were able to meet either the 1977 mean or maximum suspended solids limits. Plants 1A, 3A, and 7A were closest to meeting the 0.25 kg/kkg LWK average limit, but none were near the established maximum value.

It should be noted that the average reported for each of the plants is a long-term average and not the maximum average for a 30-day period as specified in the guidelines. Because past monitoring policies were not established to meet the present system of effluent limitations, it was believed that reporting the data as a maximum average for a 30-day period did not truly reflect the capabilities of the treatment system. This was considered, but in some cases with infrequent sampling, the maximum average for a 30-day period approached the maximum daily value. In other cases, with more frequent sampling, the maximum average for a 30-day period was in fact less than the long-term average.

The treatment system employed by plant 3A produced the lowest mean and maximum BOD_5 and suspended solids loads of the six meat-packing plants. This system consisted of an anaerobic contact process and anaerobic-aerobic stabilization ponds. As mentioned previously, all others made use of an anaerobic-aerobic lagoon system.

Since there is a lack of diversity and number in the type of treatment systems employed, no attempt is made to judge one system type better than another. Of the ones represented here, the ability of one to perform more effectively than the other is assumed then to be based on the operation of the plant.

An attempt was made to determine the cause of the occasions when the maximum allowed limits were exceeded. This was done using what information was available in regard to weather conditions and plant

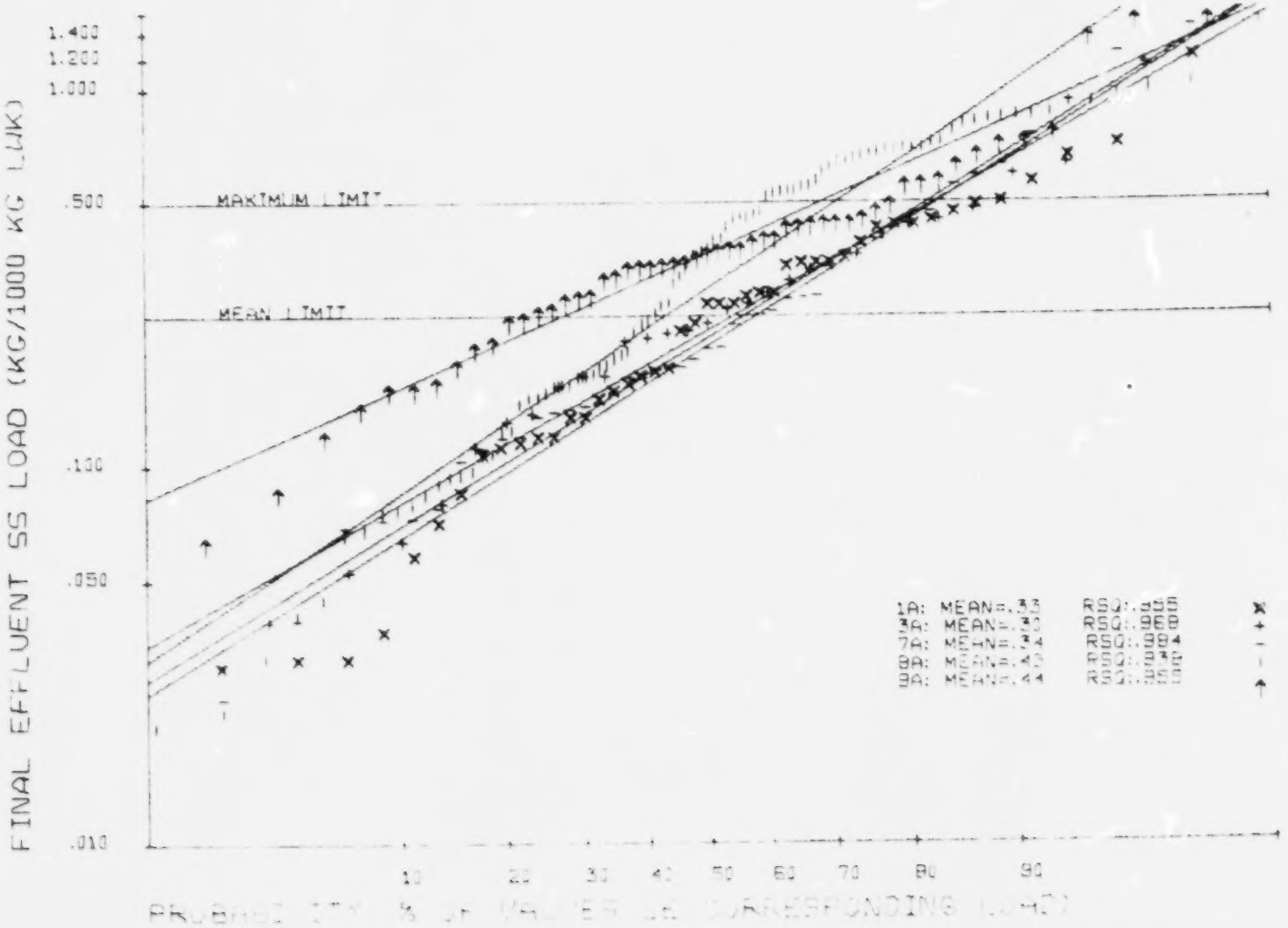

Figure 6. Log-probability representation of wastewater plant final effluent SS waste load. Data are plotted

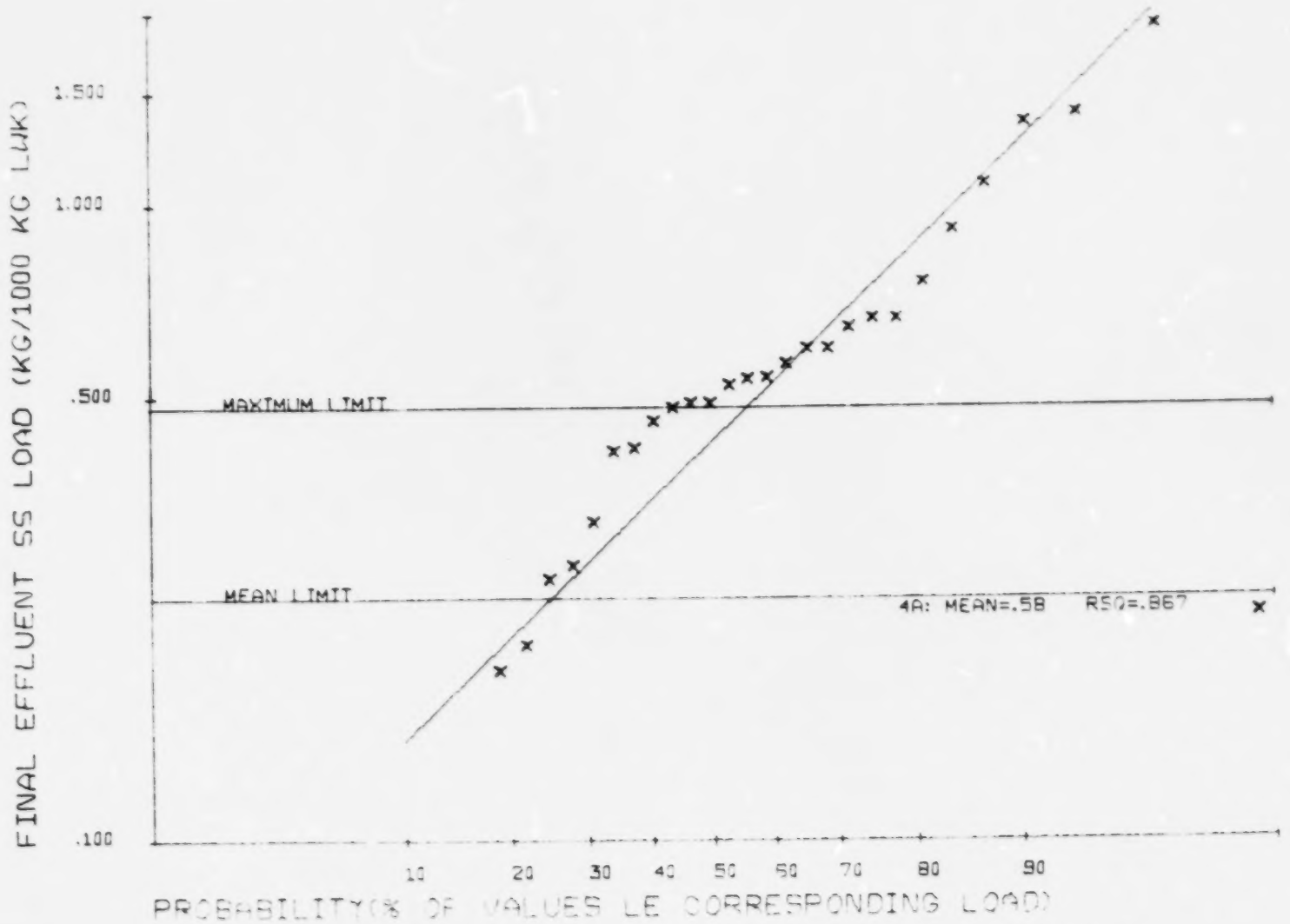

Figure 7. Log-Probability representation of meat-packing plant final effluent SS waste load, Category III plant.

processes. The extent of the data varied widely from plant to plant. In some cases, when data permitted, an attempt was made to determine if the treatment plant was operating under normal loading or if some in-plant upset occurred which might affect the treatment system. In regard to weather data, extremes in temperature and periods of high rainfall were variables in which data was more readily available that might aid in drawing some conclusion as to the operation of the treatment plant.

Beginning with plant 1A and making use of the basic data, events of high effluent load, both BOD_5 and suspended solids, are presented when available in Table 5 with an explanation of the prevailing operating conditions.

From looking at those conditions, it is assumed that extremes in weather affected the performance of the lagoon systems used in the plants. For plants 1A, 7A, and 8A all periods of ineffective operation coincided with either unusually cold weather or periods of high rainfall which produced an effluent flow greater than normal. These unusual operating conditions account for the occasions when the established 1977 effluent limitations were exceeded.

Table 6 shows the frequency of occurrence of values less than or equal to the 1977 mean and maximum effluent limitations based on the predicted curves of Figures 4-7. Plants 1A, 3A, and 7A are the only ones that might be capable of meeting the mean or 30-day average limitation for suspended solids. Of these plants the maximum limitation can only be met up to 85 percent of the time. The other 15 percent would be out of compliance.

Table 5. HIGH EFFLUENT LOAD OPERATING CONDITIONS

Plant	Effluent Parameter	Date	Condition
1A	BOD_5	2/10/72	Period of sub-zero temperature, snow, and treatment plant overloaded
	SS	2/24/72 3/9/72	Temperature near or below freezing, no overload
4A	BOD_5	5/17/71	BOD_5 70 mg/l (20 mg/l influent to final lagoon), flow and production normal.
		4/24/74	BOD_5 50 mg/l, 2nd highest reported between 3/71 and 4/74
	SS	5/17/71	SS 250 mg/l (200 mg/l influent to final lagoon)
		4/17/72	SS 240 mg/l (110 mg/l influent to final lagoon)
7A	BOD_5	1/25/73	Final flow normal
		7/13/73	" " "
		5/24/74	" " "
	SS	6/20/72	Rain, final flow normal
		10/24/72	2" rain in previous 2 days, high flow, SS 133 mg/l
		4/23/74	2 1/2" rain, high flow, SS 140 mg/l.
8A	BOD_5	5/11/72	Rain, final flow normal
		11/8/72	flow normal
		11/15/72	" "
	SS	5/4/72	1" rain, flow normal
		6/15/73	flow normal, SS 136 mg/l

Table 6. FREQUENCY OF OCCURRENCE OF VALUES ≤ 1977 EFFLUENT LIMITATIONS

(From predicted curves, in percent)

Plant	BOD_5		SS	
	Mean	Max	Mean	Max
1A	82	93	56	82
3A	89	100	57	82
4A	68	96	25	55
7A	38	78	54	82
8A	80	95	44	71
9A	64	87	28	68

Poultry: Raw Wastewater

Table 7 shows the mean raw BOD_5 and SS wastewater loads from poultry processing plants. Raw wastewater quality data was very limited, with only two of the plants having BOD_5 data and one with SS data. The two, both broiler processing plants, were quite different in terms of raw waste load, 6.4 vs. 36.7 kg/1000 kg LWK. Figures 8 and 9 show the variability of the raw waste load on a probability basis. One factor that would account for part of the variation in the load between the two plants is that plant 2B does not engage in further processing or rendering. However, the low wastewater load of plant 2B should merit further attention. Shown also in Table 7 is the water use by the four poultry processing plants in this study. Carawan, et. al., (2) concluded that lower water use in a poultry processing plant reduces the raw wastewater load. Plant 2B instituted a water conservation program in which the use dropped from approximately 42 to 26 liters per bird. Water reduction measures

Table 7. RAW WASTEWATER CHARACTERISTICS

Plant	Effluent Guidelines Category	BOD_5[a] Mean	Max	Std. Dev.	N[b]	SS[a] Mean	Max	Std. Dev.	N	Water Use[c]
2B	Broiler	6.4	15	2.2	62/8	12	41	7.0	61/8	26.0 (6.9)
3B	Duck	--	--	--	--	--	--	--	--	26.7 (7.06)
5B	Broiler	--	--	--	--	--	--	--	--	67.4 (17.8)
6B	Broiler	36.7	52	11.8	10/5	--	--	--	--	42.8 (11.3)

[a]Values in kg/kkg LWK.

[b]N=number of observations/number of months in observation period

[c]Water use in liters/bird (gal/bird)

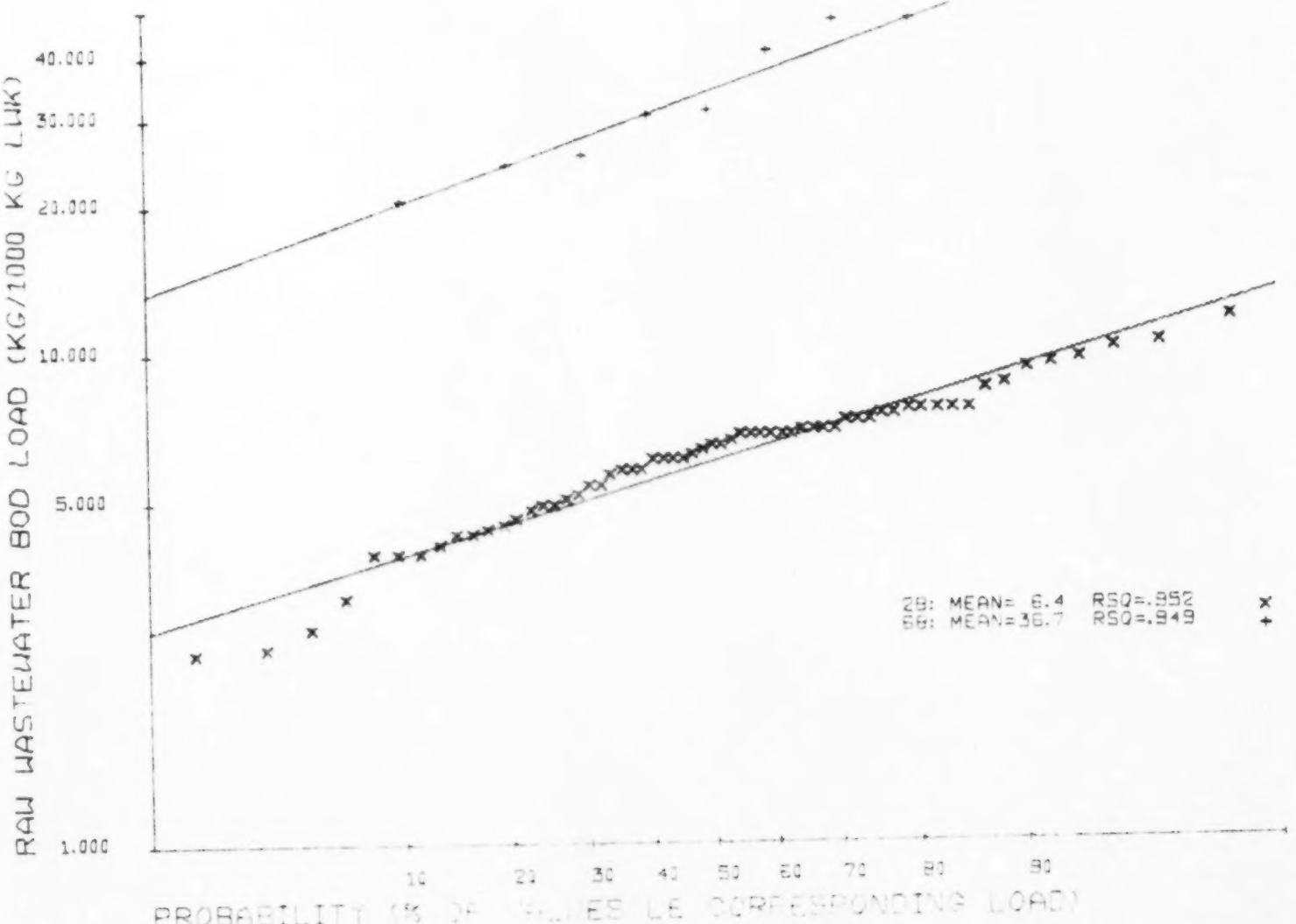

Figure 9. Log-Probability representation of poultry processing plant raw BOD_5 waste load.

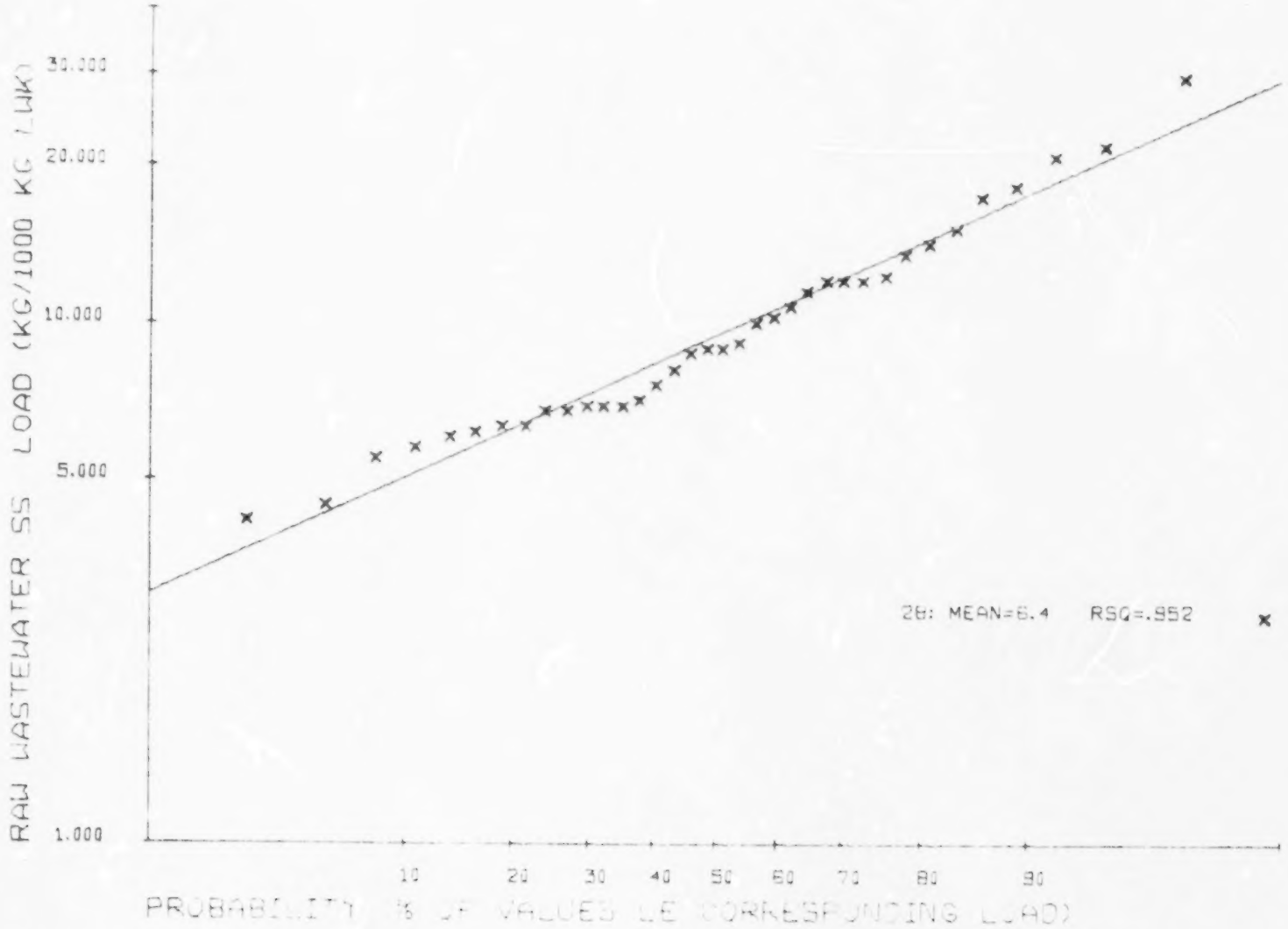

Figure 9. Log-Probability representation of poultry processing plant raw SS waste load.

consisted of an employee awareness program, daily inspections, elimination of piping leaks and the use of hoses where possible, and automatic shut off valves on essential hoses. Supply lines were equipped with valves to allow for flow regulation. Dry cleanup was practiced prior to washdown with a portable high pressure cleaning system. Lastly, chill vat water was recycled for reuse in the scalder. It is assumed, based on Carawan's earlier conclusions, that the water conservation measures undertaken by plant 2B are largely responsible for the lower raw waste load of the plant.

As an additional note plant 3B, the other plant with low water use, instituted water conservation measures. These consisted of a water pressure reduction from 414 to 138 kN/m^2 (60-20 psi), installation of spray type hand washers, use of high pressure-low water systems in clean-up, and cutoff in flow trough system to stop water flow when lines are not running.

Poultry: Final Effluent

Table 8 summarizes the results of treatment systems employed in the poultry processing industry. Biological secondary systems used are aerated lagoons, anaerobic-aerobic lagoon system, and activated sludge.

Due to the guidelines regarding effluent limitations not being finalized at the time of this writing, the results obtained by the plants in this study are compared to the 1977 values recommended by the contractor to EPA. These are not to be taken as a limit, but only a value from which to compare the results obtained here. As with the meat-packing plants, the averages presented are the long-term averages and not the maximum average for a 30-day period.

Table 8. FINAL EFFLUENT CHARACTERISTICS

Plant	Category	BOD_5[a] Mean	Max	Std. Dev.	N[b]	SS[a] Mean	Max	Std. Dev.	N
2B	Broiler	.40	1.7	.35	102/11	1.0	3.5	.79	102/11
3B	Duck	.18	.56	.11	46/27	.32	1.35	.23	47/27
5B	Broiler	.67	1.2	27	36/5	1.61	4.8	1.33	28/5
6B	Broiler	.29	1.2	.24	68/8	--	--	--	--

[a]Values in kg/kkg LWK

[b]N = number of observations/number of months in observation period.

Of the four plants presented, two of the recommended categories are represented. These are the duck processor and the broiler processor with one of the broiler processors (6B) engaged in further processing and rendering.

Table 8 and Figure 10 show that two of the broiler processors and the duck processor would meet the average BOD_5 limits. The maximum daily value, of the plants within the recommended average varies in the range of 1.8 - 4.2 times the mean obtained by these plants. Based on the recommended averages of 0.46 and 0.77 kg BOD_5/kkg LWK for plants 2B and 3B, respectively, the maximum would be 3.7 and 0.73 times the average. Plant 3B is a case where the values are so low as to make the maximum less than the recommended average. Plant 6B, with the maximum 4.1 times its average or 1.7 times the recommended average is a special case since this plant also handles further processing and rendering operations. Though it would meet the more stringent BOD_5 limit for a normal broiler processing plant, its mean value of 0.29 kg/kkg LWK would readily be in compliance with the 0.72 kg/kkg LWK recommended limit based on an adjustment factor for the ancillary operations. Figures 11, 12, and 13 show the probability curves developed to graphically show the BOD_5 variability of the effluent for these plants.

Table 8 also shows the suspended solids levels obtained by all the plants except 6B and these are compared to the recommended limits in Figure 10. Only one of these (3B) was able to meet the recommended limits and it did so readily, with the maximum of 1.35 kg/kkg LWK being greater than the recommended average of 0.90 kg/kkg LWK by a factor of 1.5. Figures 14 and 15 graphically show the suspended solids variability by the use of probability plots.

The treatment system employed by plant 3B consists of in-plant screening followed by three aerobic lagoons in series. This plant also made use of extensive wat nservation practices as mentioned earlier.

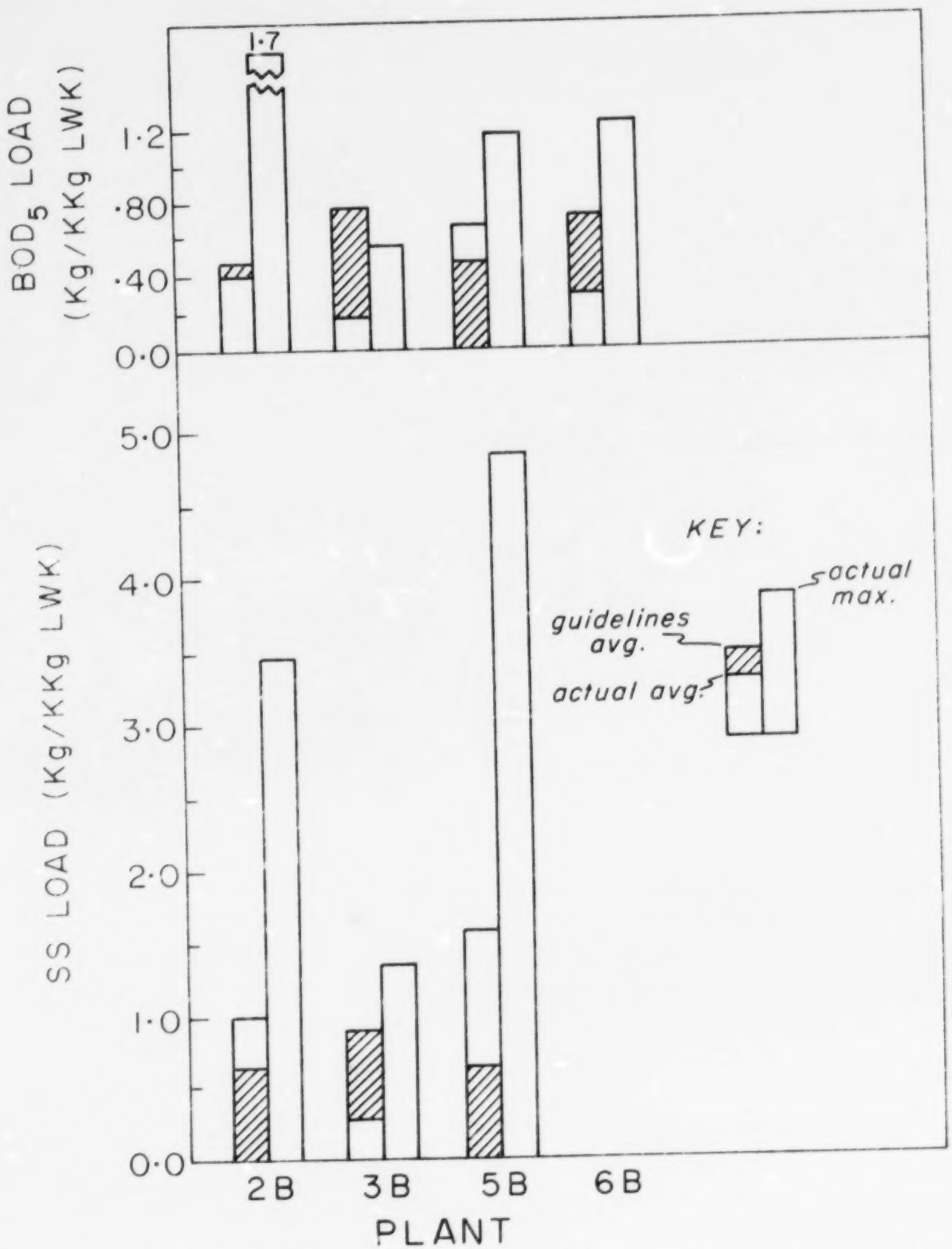

Figure 10. BOD_5 and SS actual mean and maximum vs. 1977 recommended guidelines mean.

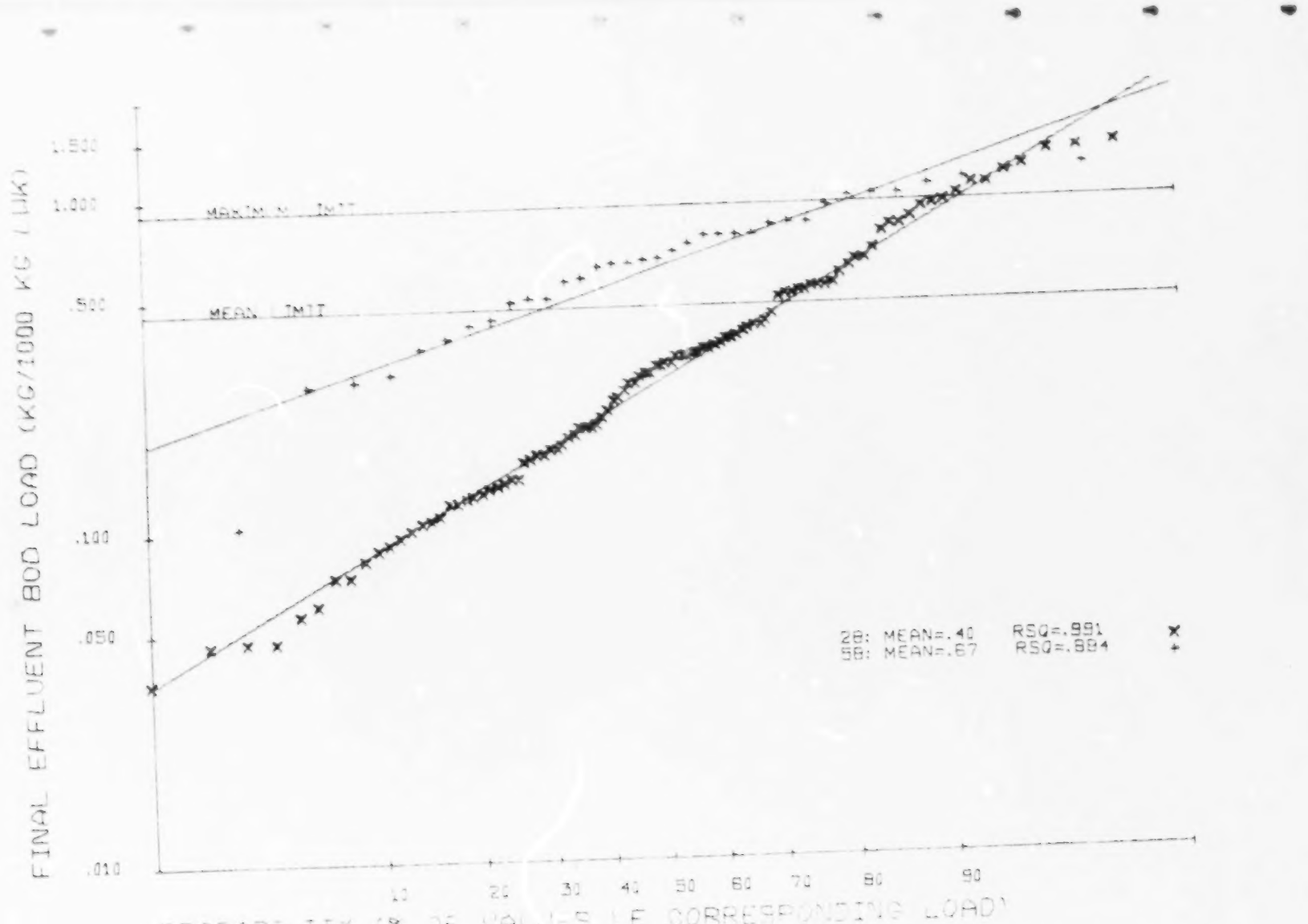

Figure 7.4. Log-probability plot of daily poultry processing plant final effluent BOD_5 waste load, broiler category.

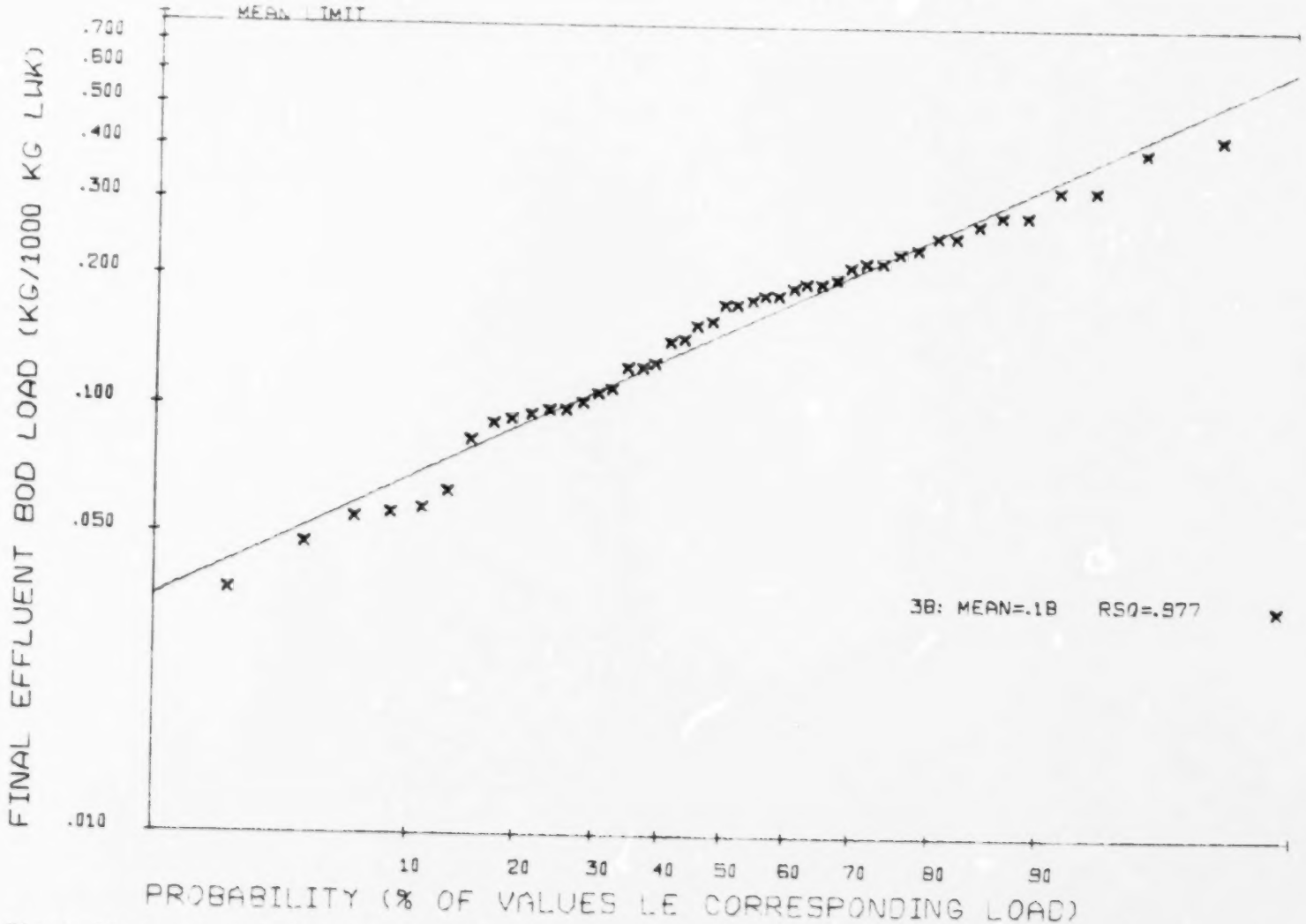

Figure 12. Log-Probability representation of a poultry processing plant final effluent BOD_5 waste load, duck category.

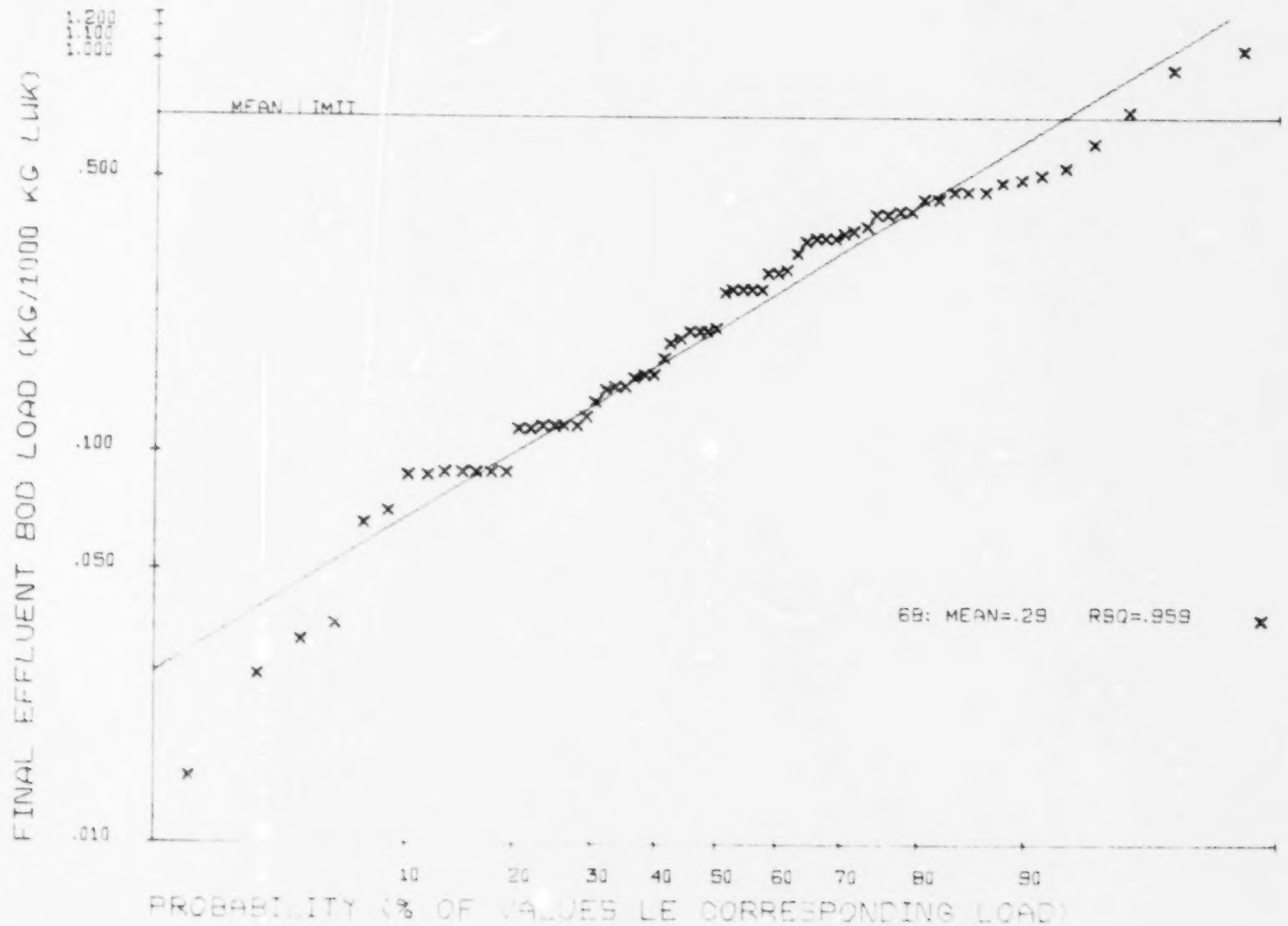

Figure 13. Log-Probability representation of poultry processing plant final effluent BOD_5 waste load, broiler category, plus further processing and rendering.

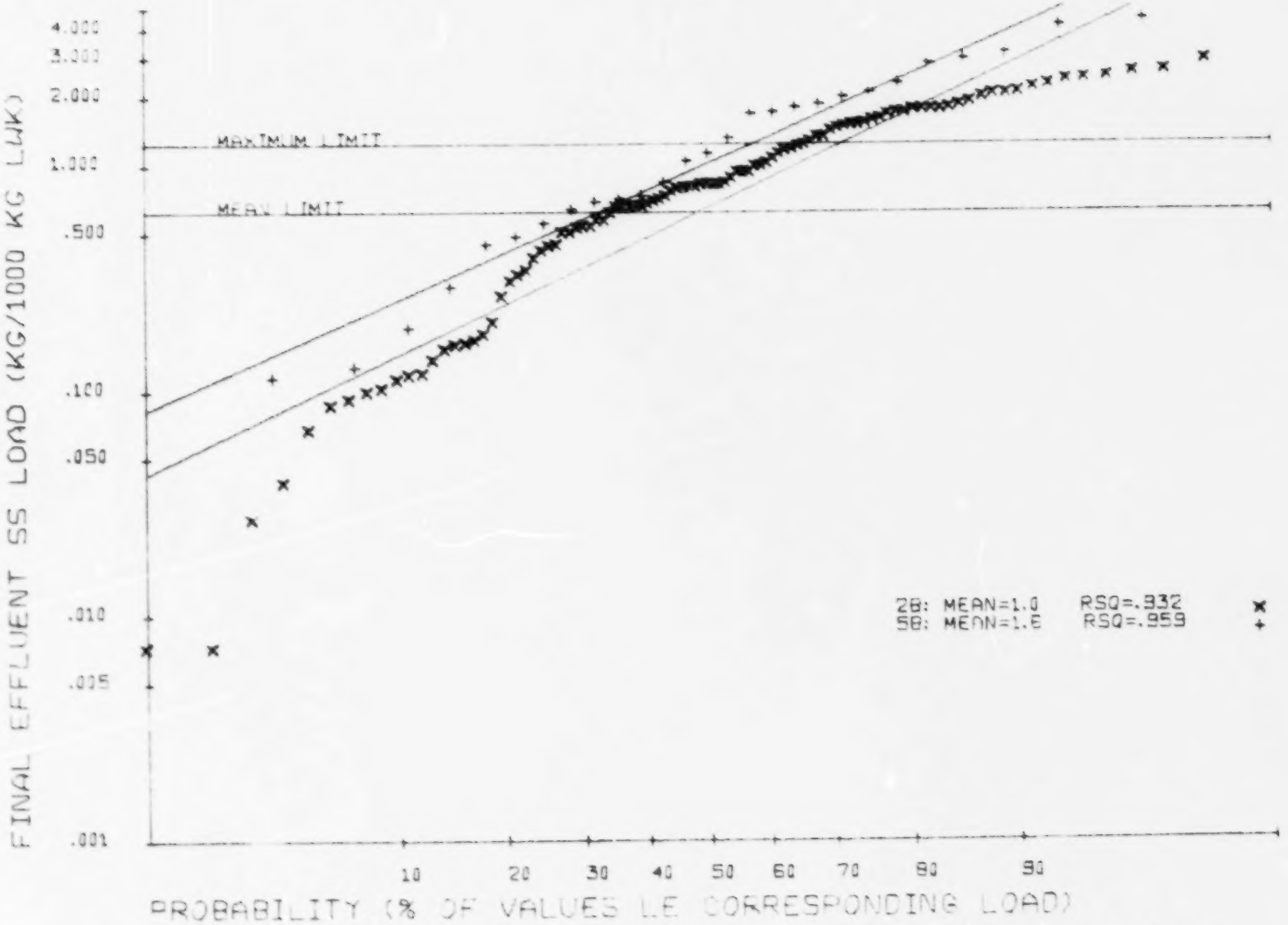

Figure 14. Log-Probability representation of poultry processing plant final effluent SS waste load, broiler category.

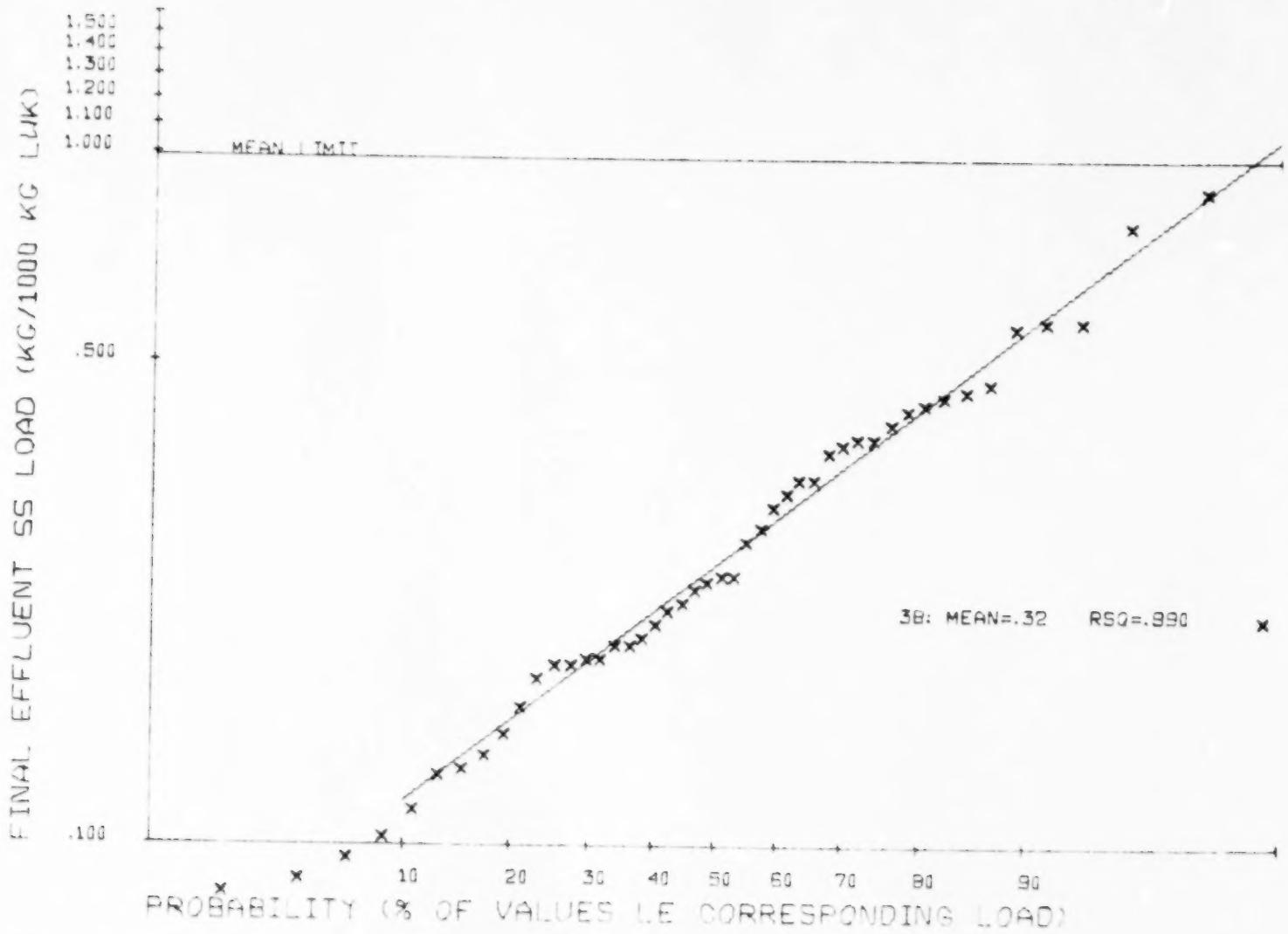

Figure 15. Log-Probability representation of poultry processing plant final effluent SS waste load, duck category.

Plant 6B, producing a low BOD_5 load, also is capable of effective suspended solids treatment. Sufficient data was not available to properly evaluate it, but it has been able to produce an effluent suspended solids of 5 mg/l. This system consists of a grease trap, wet well, holding tank, chemical mixing, flotation, activated sludge, two-parallel microstrainers, and a chlorine contact tank.

As with the meat-packing plants an attempt was made to determine the cause for the extremely high values. Information on weather conditions and plant processes is not as complete as meat-packing plants and there is adequate data on only one plant, 3B. Table 9 presents the periods of high effluent-loads with an explanation of the prevailing operating conditions. In all cases of high effluent BOD_5 or SS loads there also existed an unusual weather condition, either heavy rainfall or high wind. This plant has since made provisions to eliminate rainfall runoff from its treatment system.

Table 9. HIGH EFFLUENT LOAD OPERATING CONDITIONS

Plant	Effluent Parameter	Date	Condition
3B	BOD_5	8/9/72	Heavy rain, high runoff
		6/25/73	Heavy rain, muddy outlet
		9/5/73	High discharge, affected by summer rainfall
	SS	8/9/72	Heavy rain, high runoff
		8/28/72	High wind, SS 100 mg/l
		10/9/72	Heavy rain

Table 10 shows the frequency of occurrence of values _ the 1977 mean effluent limitations based on the predicted curves. Plants 2B, 3B, and 6B are capable of meeting the mean BOD_5 effluent limitation with at least 72 percent of their values being lower than the recommended mean. For 3B and 6B, this value increases to 92 and 100 percent, respectively. With respect to suspended solids, only 3B falls within the recommended average greater than 50 percent of the time, in this case 100 percent. It is noted again that there was not sufficient data to evaluate plant 6B for SS.

Table 10. FREQUENCY OF OCCURRENCE OF VALUES _ RECOMMENDED 1977 EFFLUENT LIMITATIONS

(From predicted curves, in percent)

Plant	Mean BOD_5	Mean SS
2B	65	35
3B	100	100
5B	25	25
6B	100	--

Winter-Summer Variation of Treated Effluent

Both the meat-packing and poultry processing plants were tested for any winter versus summer variation. The summer being classified as May through October. The means and variances were tested for equality at a confidence level of 95 percent. Table 11 shows the results of the statistical tests performed on the means and variances. No clear pattern could be detected for the variation. Plants 1A and 4A, which both meet the 1977 BOD_5 limits but not the suspended solids limits, were

the only meat-packing plants meeting the test for the equality of the means. Plant 4A also meets the criteria for equality of the variances at a 95 percent confidence level. All other meat-packing plants fail the test except for 3A which did not have sufficient data for comparison.

Table 11. RESULTS OF STATISTICAL TESTS FOR WINTER-SUMMER EQUALITY OF MEANS AND VARIANCES

(Tests conducted at a 95% confidence level; "1" implies passing the test, "0" does not; first two digits relate to BOD_5 mean and variance, second two are for SS.)

Plant	Results
1A	1010
4A	1111
7A	0000
8A	0101
9A	0100
2B	1111
6B	11--

Plants 2B and 6B, the two poultry processors tested for any winter-summer variation, both met the tests for the equality of the means and variances with respect to any BOD_5 or suspended solids variation except for 6B which had no suspended solids data. With respect to ability to meet the 1977 recommended effluent limitations, plants 2B and 6B readily meet the BOD_5 guidelines, but 2B is not able to meet the suspended solids limits.

Summary and Conclusions

The results on the raw waste load tend to support conclusions reached by Carawan (2) that lower water use reduces the raw waste load. Plants that instituted a water use reduction program also had a corresponding wastewater load reduction.

On a long-term basis, the meat-packers appear to be capable of meeting the 1977 limitations on BOD_5, but for suspended solids the maximum daily value is critical. Of the six plants in this study, the most effective one exceeded the maximum suspended solids limitation 15 percent of the time.

Based on the recommended guidelines for the poultry processing industry, there are plants in existence that can readily meet the 1977 BOD_5 and suspended solids limitations. The 1983 BOD_5 average limits are being met by two of the plants, a duck processor and the broiler or chicken processor that engages in further processing and rendering. The duck processor is also able to meet the 1983 maximum BOD_5 and average SS limitations assuming the maximum limit will be established as 2X the average.

For both the meat-packer and poultry processor, periods of high effluent load coincided with periods of abnormal weather conditions. In the case of the meat-packing plants, where sufficient data was available, all occasions of exceeding the maximum limitation were accompanied by severe weather conditions.

Of the plants evaluated in this study, there is no conclusive evidence as to the variability of the effluent with respect to winter-summer. Overall performance of a treatment plant appeared to have no effect on the variability with respect to the seasons.

Due to lack of diversity and number, it was not possible to comparatively evaluate the effectiveness of the treatment systems. For the meat-packing industry, both treatment systems of an anaerobic contact system followed by aerobic stabilization ponds and anaerobic-aerobic lagoon systems were similarly effective. For the poultry processing industry, effective treatment was provided by three different biological secondary systems; aerated lagoons, anaerobic-aerobic lagoons, and activated sludge. The wastewater management systems employing the aerated lagoons (three in series) and the activated sludge were more readily able to meet the recommended effluent limitations. The latter system consisted of a grease trap, wet well, holding tank, chemical mixing, flotation, activated sludge, two-parallel microstrainers, and a chlorine contact tank.

Inferences drawn from the plots of the effluent load versus frequency for the meat-packing and poultry plants are that in order to stay within the maximum limitation, an average less than the 30-day average limit will be necessary. This is due to the fact that the maximum value of the effluent load is greater than twice the average load. Some plants, as in the case of BOD_5 for 6B, even though the maximum value is greater than 2X the mean, both fall within the average and maximum limits due to the low average value. Since a plant such as this is weighted more heavily in the lower range of values, it is to be expected that the maximum would be greater than 2X the average due to the range of effluent loads inherent to the system.

Relating the results to the enforcement of the established guidelines would lead one to question the enforceability of the maximum limit. Using the system of plant 1A, the maximum allowed BOD_5 value was exceeded only one time in forty-three samples. For monthly or weekly sampling this would result in a probability of sampling on a day that the maximum

was exceeded of only $2x10^{-9}$ and $5x10^{-5}$ respectively. See appendix for calculation. In any plant that exceeded this limit frequently enough to cause enforcement action, the high results would increase the mean such that enforcement of these extreme values would be covered in the mean.

This leads to a system proposed for one by Popel (3) in which a combined standard would be established with a set limit and an allowed probability of exceeding it. To illustrate this concept, the results of plant 6B are plotted again in Figure 16 as in Figure 13, except this time using an arithmetic scale. This more effectively shows the point at which the treatment efficiency falls off. The combined standard would set the limit at this point, or the 90 percent level in this case. This would allow for the few occasions of the less effective plant operation that might be due to weather conditions, but in actuality would closely represent the true performance of the treatment system for a major percentage of the time.

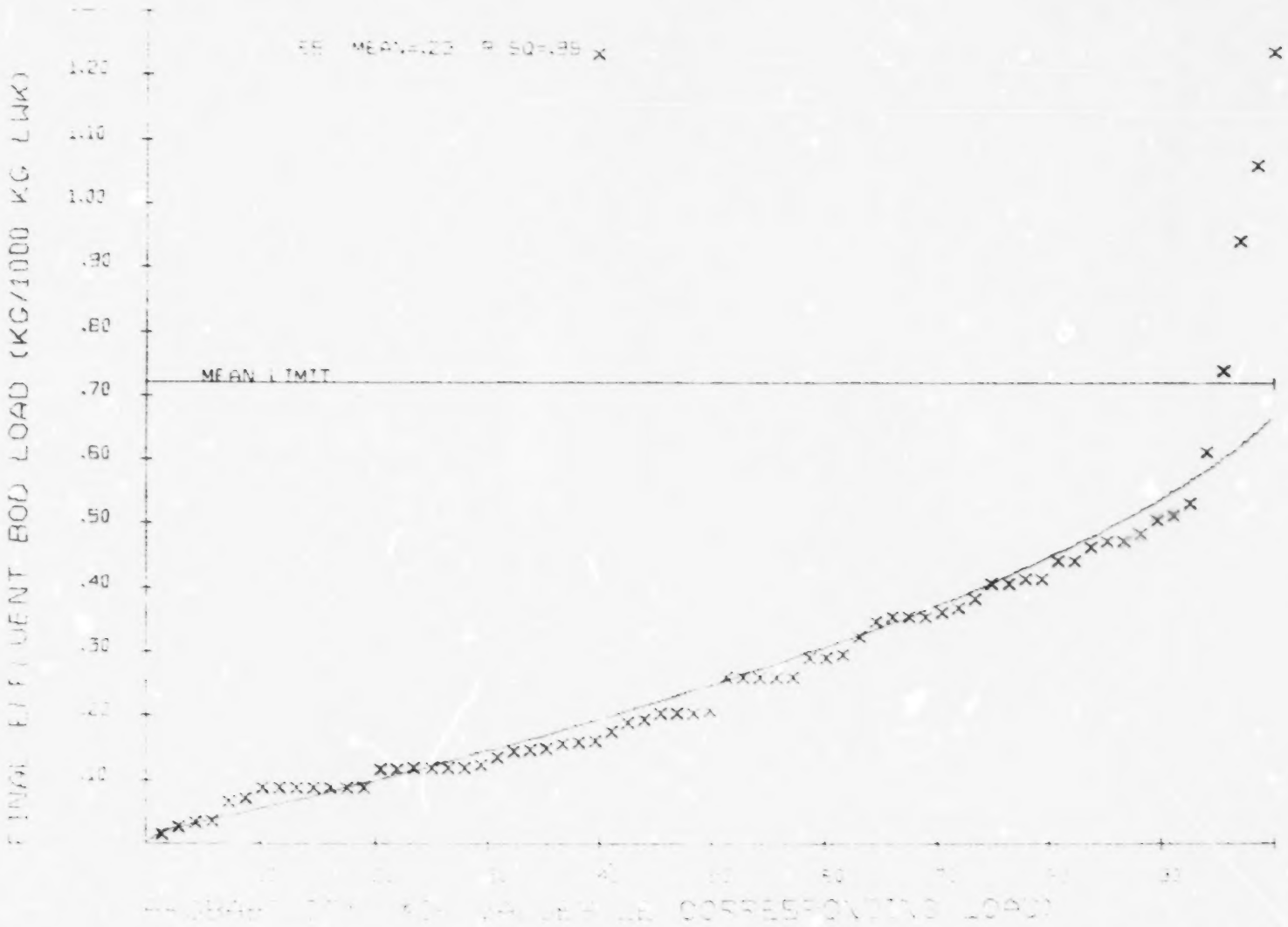

Figure 16. Arithmetic representation of plant 6B final effluent BOD_5 load and frequency of occurrence.

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2. Carawan, Roy E., W. M. Crosswhite, J. A. Macon, and B. K. Hawkins. Water and Waste Management in Poultry Processing. EPA-660/2-74-031, May 1974.

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APPENDIX

Explanation of Abbreviations Used

BOD_5:	5-day Biochemical Oxygen Demand
TSS:	Total Suspended Solids
SS:	Suspended Solids, same as TSS
O&G:	Oil and Grease
NH_3-N:	Ammonia Nitrogen
NO_3/NO_2-N:	Nitrate-Nitrite Nitrogen
TKN:	Total Kjeldahl Nitrogen
TP:	Total Phosphorus
mpn:	Most probable number
kg/kkg LWK:	Kilograms per 1000 kilograms live weight killed
m:	Meter
l:	liter
kN/m^2:	Kilonewton per square meter
psi:	pounds per square inch
":	inch
LE:	less than or equal to

Equations Used for Calculation of Adjustment Factors for Plant 6B (Poultry)

For 1977 Discharge limitations:

Rendering

BOD_5: (.15 kg BOD_5/kkg RM) (kkg RM,/kkg LWK)

SS: (.17 kg SS/kkg RM) (kkg RM/kkg LWK)

Further Processing

BOD_5 (.30 kg BOD_5/kkg FP) (kkg FP/kkg LWK)

SS: (.35 kg SS/kkg FP) (kkg FP/kkg LWK)

For 1983 Discharge Limitations

Rendering

BOD_5: (.07 kg BOD_5/kkg RM) (kkg RM,/kkg LWK)

SS: (.10 kg SS/kkg RM) (kkg RM/kkg LWK)

Further Processing

BOD_5: (.15 kg BOD_5/kkg FP) (kkg FP/kkg LWK)

SS: (.18 kg SS/kkg FP) (kkg FP/kkg LWK)

where

RM = amount of raw materials rendered on site
FP = amount of further processing done

BOD_5 (adjusted) = BOD_5 (recommended for subcategory) + BOD_5 (rendering) + BOD_5 (further processing)

SS (adjusted) = calculate same as for BOD_5

Calculation of Probability of Sampling the Occasion of Maximum Effluent Load

From Burr (4)

$$C(n,r) = P(n,r)/P(r,r)$$
$$= n!/r!(n-r)!$$

where

C(n,r) is the desired number of combinations of n different things r at a time,

P(n,r) is the number of permutations of n different objectives taken r at a time, and,

P(r,r) is the number of different orders in which all of r objects may be drawn.

For the case of monthly sampling, or 12 samples in 260 working days and a violation that occurs 1 in 43 (6 in 260) working days.

C(254,6) = number of 12-sample monitoring schedules that contain all 6 violations in a 260-day sampling period.

C(260,12) = number of 12-sample monitoring schedules in 260-day sampling period, and

P(6 violations) = C(254,6)/C(260,12)

Where P(6 violations) is the probability of sampling the six violations.

$$C(254,6) = 254!/6!(248!)$$
$$C(260,12) = 260!/12!(248)!$$

$P(6 \text{ violations}) = 2.28 \times 10^{-9}$

Similarly, for the case of weekly sampling, or 52 samples in 260 working days.

$C(254,46) = 254!/46!(208)!$
$C(260,52) = 260!/52!(208)!$

and,

$P(6 \text{ violations}) = 5.03 \times 10^{-5}$